Autonomous Task Primitives for Complex Manipulation Operations

Completed Technology Project (2013 - 2016)

Project Introduction

The goal of this research effort is to enable robots to autonomously perform the complex manipulation tasks that are necessary to maintain a spacecraft. Robots, like NASA's Robonaut 2 (R2), could assist human spaceflight by freeing the crew's time for more valuable activities and helping astronauts with dangerous and time-consuming tasks. These tasks include setting up and tearing down extra-vehicular activities (EVA) sites, changing air filters, and taking environmental samples on the International Space Station (ISS). Many of these tasks require tool use, dexterous manipulation, reasoning about the physics of contact, and collaboration with astronauts; e.g. handing off tools. Manipulators are currently only capable of performing these actions through direct teleoperation. Teleoperation has been successful in explosive ordinance disposal (EOD) and surgical robots, but the expertise and bandwidth required is tremendous: only trained EOD technicians and surgeons can operate these robots effectively, and it consumes all of their attention and time. These flaws are especially problematic during spaceflight because bandwidth is limited, latency is high, and communication dropouts are common. For example, ground controllers must carefully schedule remote teleoperation of R2 around ISS's KU band dropouts and continuously monitor KU band coverage during teleoperation. Our goal is to reduce the expertise and bandwidth required for manipulation by providing an extensible vocabulary of task primitives. For example, the operator could command the robot to stow everything in this box in storage, flip that switch, or pick up that drill. As a consequence, the complexity of planning and controlling the robot is abstracted away from the user, reducing bandwidth and allowing the user to focus on higher-level mission planning. This abstraction puts the burden of planning and executing complex manipulation primitives squarely on the shoulders of the robot. A vocabulary of primitives may be easily repurposed to a broad range of missions and could be reused on similar robots. Primitives are also naturally extensible: as the capabilities of the robot increase over time, so does the richness of its vocabulary. Finally, robust task primitives are an important step towards achieving fully autonomous manipulation in the long term. Primitive actions can be combined by high level planner to achieve more complex tasks without human intervention. Our goal is to implement and evaluate the task primitives on R2, and eventually, in space. As an intermediate step we will evaluate these primitives on HERB, a mobile manipulator designed by the Personal Robotics Laboratory at Carnegie Mellon University. Testing the primitives on HERB will insure that they generalize between robots and allow us to quickly evaluate their performance without spending valuable time on R2. We will then evaluate the primitives on R2 through close collaboration with Dr. Myron Diftler and the Robonaut group at Johnson Space Center. In contrast to HERB, R2 has high degree-of-freedom anthropomorphic hands and operates both on Earth and in microgravity. In the long term, these task primitives could be deployed onto the R2 stationed on ISS. We are confident that developing a library of robust task primitives would reduce the need for direct teleoperation and enable R2 to complete complex manipulation

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Anticipated Benefits

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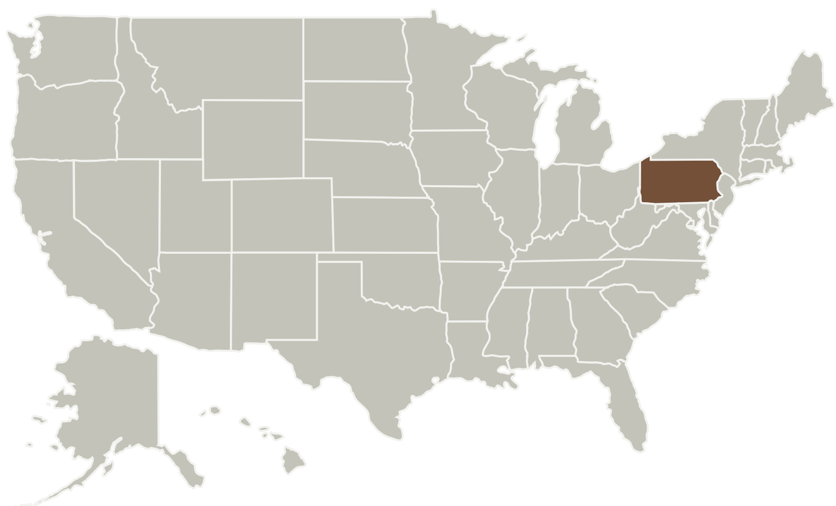
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Carnegie Mellon University	Lead Organization	Academia	Pittsburgh, Pennsylvania

Primary U.S. Work Locations
Pennsylvania

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Carnegie Mellon University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

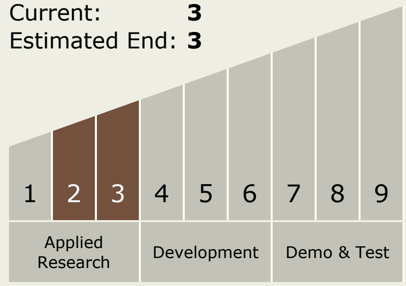
Siddhartha Srinivasa

Co-Investigator:

Michael C Koval

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX10 Autonomous Systems
  └─ TX10.2 Reasoning and Acting
    └─ TX10.2.4 Execution and Control

Target Destinations

Mars, Earth, Others Inside the Solar System